

A satellite view of the Earth from space, showing the Western Hemisphere with North and South America visible. The image has a blue and white color scheme, representing the oceans and clouds.

California Global Warming Solutions Act
of 2006

Greenhouse Gas Inventory and 1990 Emissions Level

Implementation of AB 32 Requirements

California Air Resources Board
August 13, 2007 - Cal/EPA Headquarters

Workshop Agenda

- **Greenhouse Gas Inventory**
- **Database and Documentation**
- **1990 Emissions Level**
- **2020 Projections – Ongoing Work**
- **Schedule**



Background

AB 32 Emission Inventory Activities

- Transfer from CEC to ARB on January 1, 2007
- Update statewide GHG Inventory
- Determine statewide 1990 emissions level
- Establish statewide 2020 emissions limit equal to 1990 emissions level
- Present to Board by January 1, 2008

Description of Statewide Inventory

- Emissions of six “Kyoto gases” in tonnes of CO₂ equivalents (CO₂e)
- Generally consistent with IPCC and U.S.EPA guidance
- Uses IPCC Second Assessment Report GWPs
- “Top-down” vs. “bottom-up” approaches

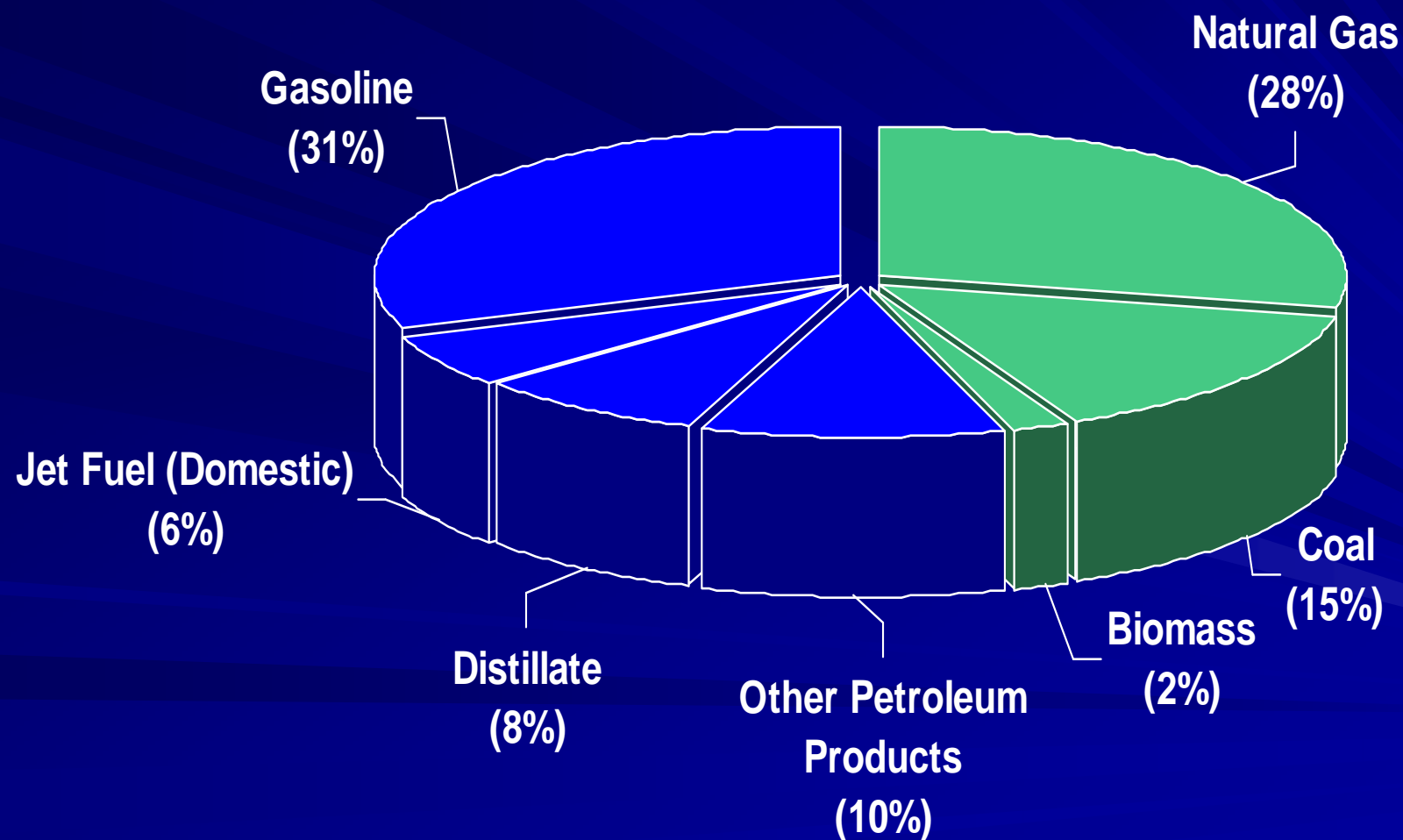
Inventory Updates

- Improved data input
 - Updated emission factors
 - Improved activity data
 - Corrected calculation errors
- Methodological improvements for some categories
- Data sources:
 - International organizations
 - Federal and state agencies
 - Stakeholders

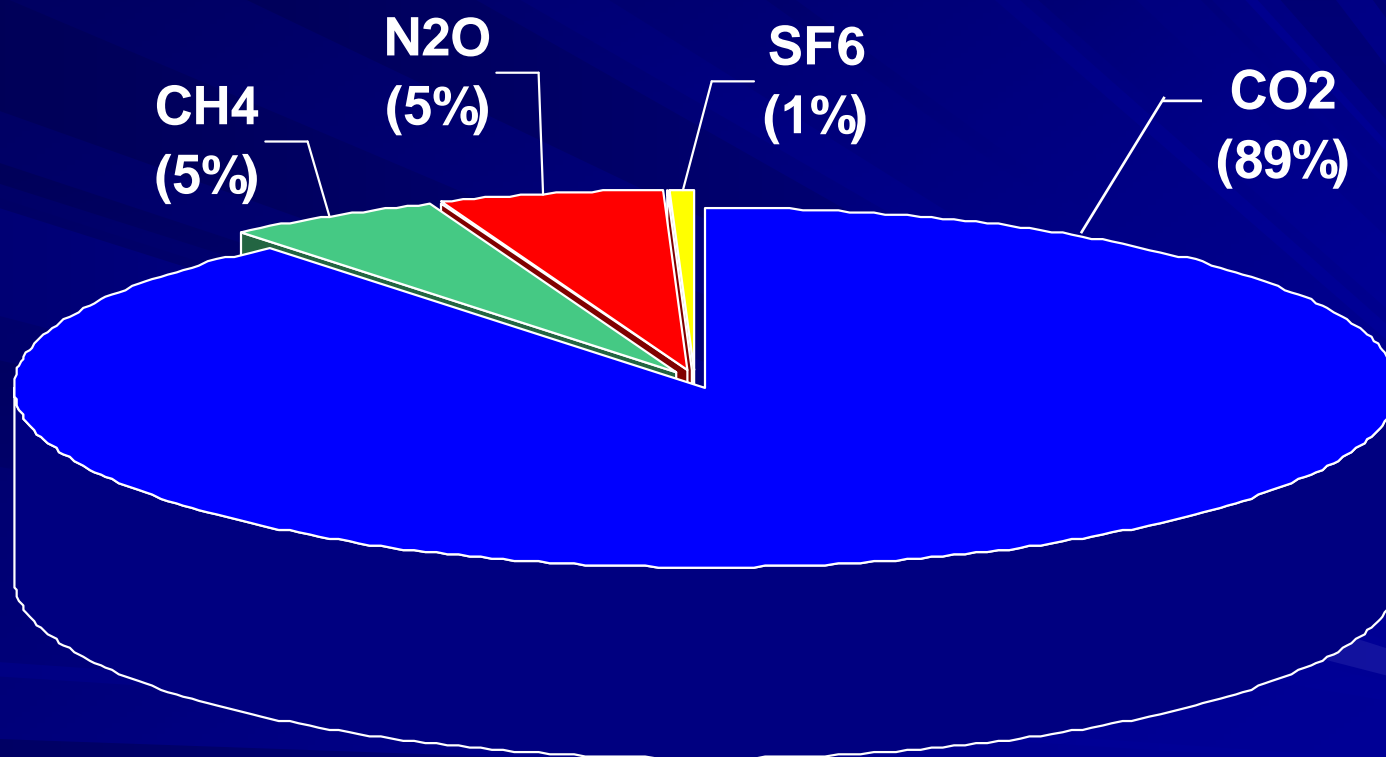
Scope of Inventory Review

- All sectors and ~270 sub-categories
- More than 10,000 calculations
- Entire inventory for 1990-2004

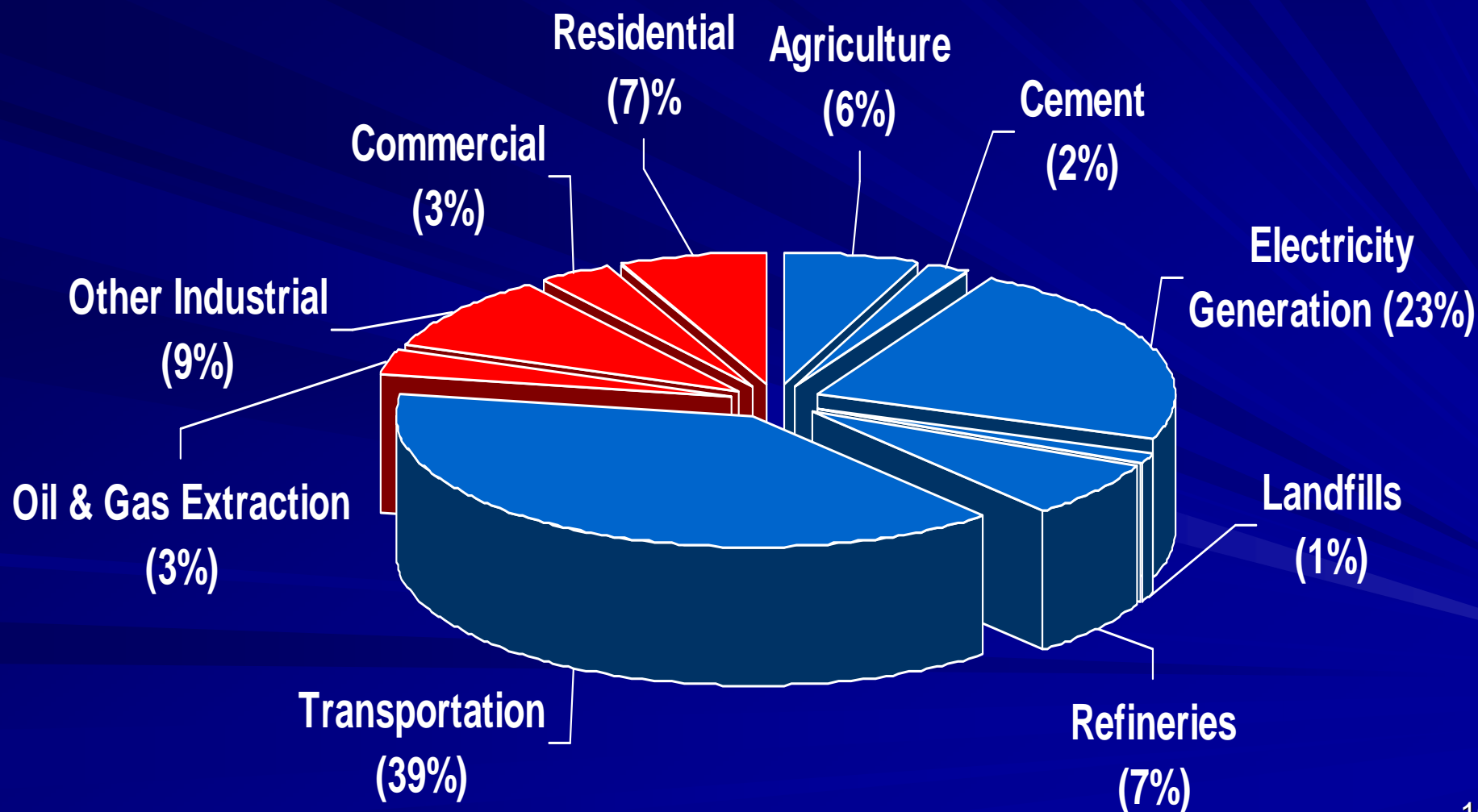
1990 Gross Emissions by Fuel (MMTCO₂ Eq)



1990 Gross Emissions by Gas (MMT_{CO2} Eq)



Updated 1990 Gross Emissions



Results of Review (MMTCO2 Eq)

Sector	1990 CEC	1990 ARB	% difference
Agriculture	27	22	-19%
Cement	5	8	60%
Electricity Generation – In-State	45	47	4%
Electricity Generation – Imported	44	53	20%
Landfills	8	7	-13%
Refineries	28	30	7%
Land Use, Land Use Change and Forestry (net, biodegradable CO2)	-17	-6	-65%
Transportation	178	171	-4%
Total (all sectors)	413	436	



Sector Technical Discussion

Focus of Inventory Review

- Agriculture
- Cement
- Electricity Generation
- Refineries
- Landfills
- Land Use, Land Use Change & Forestry
- Transportation

*~80% of
Total
1990
Emissions*

Agriculture

■ Includes:

- Manure Management
- Enteric Fermentation
- Agricultural Residue Burning
- Managed Soils

Manure Management - Updates

- Includes emissions from management of livestock waste
- Data Sources: California-specific data compiled by U.S.EPA
- Updates:
 - Used 2006 IPCC methodology
 - Used data from U.S.EPA 1990-2005 inventory

Manure Management - Estimates

- CEC 1990 estimate:
4.10 MMTCO₂ Eq
- New 1990 estimate:
5.00 MMTCO₂ Eq



Enteric Fermentation - Updates

- Includes exhaled methane emissions that are produced in animals' digestive systems
- Data Sources: California-specific data compiled by U.S.EPA
- Update:
 - Used most recent U.S.EPA model outputs

Enteric Fermentation - Estimates

- CEC 1990 estimate:
7.53 MMTCO₂ Eq
- New 1990 estimate:
6.67 MMTCO₂ Eq



Agricultural Residue Burning - Updates

- Includes emissions (CH_4 and N_2O) from burning Ag biomass waste
- Data Sources: California-specific data compiled by CEC
- Updates:
 - Accounted for rice straw phase-down
 - Revised calculations

Agricultural Residue Burning – Estimates

- CEC 1990 estimate:
0.14 MMTCO₂ Eq
- New 1990 estimate:
0.33 MMTCO₂ Eq



Managed Soils - Updates

- Includes Ag practices that add nitrogen to soil and increase N₂O emissions
- Data Sources: California-specific data compiled by CEC
- Updates:
 - Revised calculations
 - Improved emission factors

Managed Soils - Estimates

- CEC 1990 estimate:
14.68 MMTCO₂ Eq
- New 1990 estimate:
9.52 MMTCO₂ Eq



Cement

- Includes emissions from clinker production and fuel use
- Data Sources:
 - USGS statewide clinker production data
 - California Energy Balance
 - IPCC emission factors

Cement - Updates

- Updated clinker production data
- Used IPCC 2006 Revised Guidelines methodology for process CO₂ emissions
- Included 5 year average for coke and coal

Cement - Estimates

- CEC 1990 estimate:
4.80 MMTCO₂ Eq
- New 1990 estimate:
8.23 MMTCO₂ Eq



Electricity Generation

- Includes emissions from generating in-state and imported electricity
- Data sources:
 - Energy Information Administration
 - IPCC emission factors for CH₄ and N₂O

In-State Electricity Generation - Updates

- Included additional fuels (i.e., biomass, geothermal)
- Used IPCC oxidation factor of 1
- Updated SF6 emissions
- Included CHP useful thermal output in industrial and commercial sector emissions

Imported Electricity Generation - Updates

- Included 6 additional specified imports and updated 2 specified imports
- Used gross imported power
- Accounted for line loss
- Included IPCC emission factors for CH₄ and N₂O
- Used IPCC oxidation factor of 1
- Updated SF₆ emissions

Electricity Generation - Estimates



- In-State CEC 1990 estimate:
45.17 MMTCO₂ Eq
- In-State New 1990 estimate:
46.95 MMTCO₂ Eq
- Imported CEC 1990 estimate:
44.05 MMTCO₂ Eq
- Imported New 1990 estimate:
53.12 MMTCO₂ Eq

Refineries

- Includes emissions from fuel use for H₂ production, on-site fuel combustion and some fugitive emissions
- Data Source: California Energy Balance (PIIRA)

Refineries - Updates

- Included:
 - H₂ production emissions
 - Fugitive CH₄ emissions
 - CH₄ and N₂O from fuel combustion
- Used IPCC oxidation factor of 1
- Extrapolated missing data for natural gas and associated liquids

Refineries - Estimates

- CEC 1990 estimate:
27.85 MMTCO₂ Eq
- New 1990 estimate:
30.45 MMTCO₂ Eq



Landfills

- Includes emissions from decomposition of landfill material (CH_4) and burning of landfill gas (CH_4 and N_2O)
- CO_2 emissions from decomposition addressed in Land Use & Forestry
- Data Sources:
 - CIWMB for Waste in Place data and landfill controls
 - Survey data
 - IPCC, U.S.EPA and CIWMB for waste characterization
 - U.S.EPA for waste decay rate

Landfills - Updates

- Used IPCC Mathematically Exact First-Order Decay Model
- Tracks annual amount of carbon sequestered
 - Sequestered carbon not considered a sink
- Added N₂O emissions

Landfills - Estimates

- CEC 1990 estimate:
8.13 MMTCO₂ Eq
- New 1990 estimate:
6.58 MMTCO₂ Eq
- Landfill gas to energy estimate:
0.03 MMTCO₂ Eq (included in
electricity sector)



Land Use, Land Use Change & Forestry (Biodegradable CO₂)

- Includes CO₂ emissions from:

- Harvested and fuel wood
- Landfilled and composted wood products
- Biomass wildfires
- Burning of crop residues (CO₂ only)

- Includes removals from:

- Forest, rangeland and crop growth

Land Use, Land Use Change & Forestry - Updates

■ Data Sources:

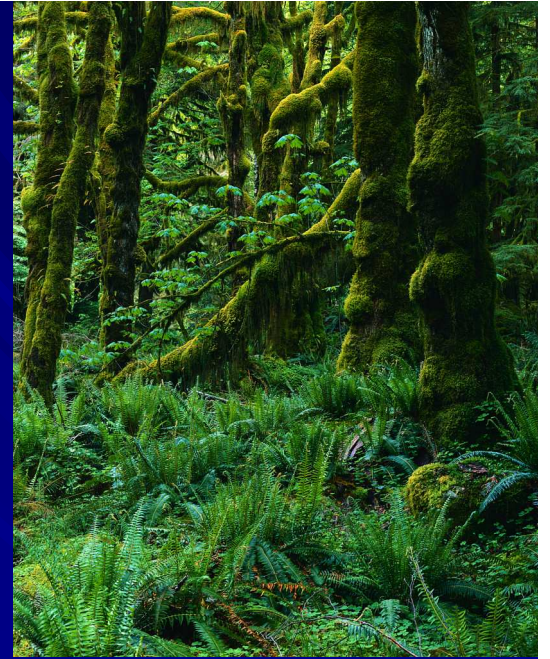
- CEC Inventory (Winrock)
- USFS and CIWMB data on wood consumption and wood landfill and composting data

■ Used IPCC Atmospheric Flow Approach to track CO₂ flux

■ Removed landfill wood products as “sinks”

Land Use, Land Use Change & Forestry - Estimates

- CEC 1990 estimates (net):
-17.16 MMTCO₂ Eq
- New 1990 estimates (net):
-5.62 MMTCO₂ Eq



Transportation

- Includes CO₂, CH₄ and N₂O emissions from:
 - Highway vehicles
 - Airplanes (domestic only)
 - Trains
 - Ships and Boats (domestic only)



Highway Vehicles - Updates

■ Data Sources:

- California Energy Balance
- EMFAC 2007

■ Updates:

- Used newer version of EMFAC for CH₄
- Updated diesel N₂O emissions

Highway Vehicles - Estimates

- CEC 1990 estimate:
147.36 MMTCO₂ Eq
- New 1990 estimate:
139.81 MMTCO₂ Eq



Trains, Ships and Planes - Updates

- Data Sources:

- California Energy Balance
- U.S.EPA emission factors for CH₄ and N₂O

- Updated CH₄ and N₂O emissions using U.S.EPA emission factors

Trains, Ships and Planes - Estimates



- CEC 1990 estimate:
30.64 MMTCO₂ Eq
- New 1990 estimate:
30.76 MMTCO₂ Eq

Pending Updates & Improvements

- Cement fuel use
- Selected industrial processes (i.e., glass container manufacturing)
- Feedstock for hydrogen production for refineries
- Burning of associated gas and crude oil for oil and gas extraction
- Emissions from managed soils



Documentation and Database

Rationale for Documentation Efforts

- Requests by stakeholders
- Need for transparency

Description of Database

- Created relational database
 - Stores equations, parameters and references
 - Calculates emissions
- Online access
 - Output available as PDF or Excel spreadsheet
 - Documentation pages

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DRAFT California Greenhouse Gas Inventory (millions of metric tonnes of CO₂ equivalent) — By IPCC Category

Last Updated: 8/7/2007 4:37:50 PM

	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002
3C - Aggregate Sources and Non-CO₂ Emissions Sources on Land	10.25	9.14	9.40	10.04	9.79	10.98	10.76	9.83	9.89	10.13	11.21	10.54	13.45
3C1 - Emissions from Biomass Burning	0.25	0.22	0.24	0.25	0.27	0.27	0.30	0.30	0.30	0.27	0.27	0.26	0.28
3C1b - Biomass Burning in Croplands	0.250	0.215	0.244	0.246	0.269	0.269	0.298	0.302	0.299	0.267	0.275	0.263	0.275
Crop acreage - Almond > CH ₄	0.008	0.007	0.007	0.008	0.009	0.009	0.009	0.009	0.010	0.011	0.011	0.011	0.011
Crop acreage - Almond > N ₂ O	0.019	0.018	0.019	0.019	0.022	0.022	0.023	0.023	0.026	0.027	0.028	0.028	0.028
Crop acreage - Barley > CH ₄	0.019	0.016	0.017	0.017	0.022	0.019	0.019	0.017	0.013	0.010	0.010	0.012	0.010
Crop acreage - Barley > N ₂ O	0.023	0.020	0.021	0.021	0.026	0.023	0.022	0.020	0.015	0.012	0.012	0.014	0.012
Crop acreage - Corn > CH ₄	0.050	0.047	0.052	0.055	0.057	0.059	0.067	0.078	0.078	0.068	0.070	0.062	0.070
Crop acreage - Corn > N ₂ O	0.042	0.040	0.044	0.047	0.048	0.049	0.057	0.066	0.066	0.067	0.069	0.052	0.059
Crop acreage - Rice > CH ₄	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Crop acreage - Rice > N ₂ O	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Crop acreage - Walnut > CH ₄	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.005	0.006	0.006	0.006	0.006	0.006
Crop acreage - Walnut > N ₂ O	0.008	0.009	0.009	0.009	0.010	0.010	0.010	0.010	0.010	0.010	0.010	0.011	0.011
Crop acreage - Wheat > CH ₄	0.042	0.029	0.039	0.036	0.040	0.040	0.048	0.040	0.042	0.036	0.039	0.038	0.038
Crop acreage - Wheat > N ₂ O	0.034	0.024	0.032	0.029	0.032	0.032	0.039	0.032	0.034	0.029	0.031	0.030	0.031
3C2 - Liming	0.07	0.10	0.11	0.07	0.16	0.27	0.27	0.35	0.25	0.30	0.27	0.16	0.23
Dolomite applied to soils > CO ₂	0.000	0.001	0.001	0.001	0.002	0.003	0.004	0.005	0.003	0.004	0.003	0.001	0.002
Limestone applied to soils > CO ₂	0.072	0.098	0.108	0.073	0.157	0.271	0.267	0.348	0.246	0.294	0.263	0.161	0.231
3C4 - Direct N₂O Emissions from Managed Soils	6.07	5.42	5.47	5.81	5.62	6.17	6.00	5.39	5.50	5.62	6.18	5.88	7.57
Histosols cultivation > N ₂ O	0.181	0.178	0.175	0.172	0.169	0.166	0.163	0.160	0.157	0.154	0.151	0.148	0.145
Nitrogen applied in fertilizer - Organic fertilizers > N ₂ O	0.015	0.011	0.015	0.008	0.021	0.019	0.016	0.007	0.007	0.006	0.044	0.013	0.021
Nitrogen applied in fertilizer - Synthetic fertilizers > N ₂ O	2.816	2.268	2.458	2.919	2.543	3.328	3.154	2.534	2.695	2.720	3.320	3.058	4.599
Nitrogen fixed by legume crops > N ₂ O	1.315	1.280	1.155	1.074	1.180	0.990	0.991	1.040	1.019	1.087	1.062	1.039	1.174
Nitrogen in crop residues > N ₂ O	0.116	0.091	0.096	0.097	0.102	0.086	0.097	0.100	0.098	0.097	0.101	0.135	0.153
Nitrogen in manure deposited on pasture range > N ₂ O	1.549	1.516	1.494	1.455	1.517	1.490	1.488	1.455	1.434	1.463	1.404	1.390	1.388
Nitrogen in manure spread daily > N ₂ O	0.078	0.079	0.081	0.083	0.085	0.086	0.088	0.090	0.091	0.095	0.099	0.103	0.107
3C5 - Indirect N₂O Emissions from Managed Soils	3.45	3.04	3.16	3.46	3.24	3.79	3.68	3.26	3.36	3.42	3.92	3.75	4.83
Nitrogen applied in fertilizer - Organic fertilizers > N ₂ O	0.003	0.002	0.003	0.002	0.004	0.004	0.003	0.001	0.001	0.001	0.009	0.003	0.004
Nitrogen applied in fertilizer - Synthetic fertilizers > N ₂ O	0.250	0.202	0.219	0.259	0.228	0.296	0.280	0.225	0.240	0.242	0.295	0.272	0.409
Nitrogen applied in fertilizer (leaching & runoff) - Organic fertilizers > N ₂ O	0.009	0.007	0.009	0.005	0.013	0.011	0.010	0.004	0.004	0.004	0.026	0.008	0.013
Nitrogen applied in fertilizer (leaching & runoff) - Synthetic fertilizers > N ₂ O	1.690	1.361	1.475	1.751	1.528	1.997	1.893	1.520	1.617	1.632	1.992	1.833	2.780
Nitrogen in manure (leaching & runoff) > N ₂ O	1.133	1.112	1.102	1.091	1.115	1.125	1.128	1.139	1.137	1.165	1.211	1.231	1.241
Nitrogen volatilized from manure on soils > N ₂ O	0.361	0.354	0.352	0.349	0.357	0.361	0.362	0.366	0.365	0.374	0.393	0.399	0.403
3C7 - Rice Cultivations	0.41	0.36	0.41	0.45	0.50	0.48	0.52	0.54	0.47	0.52	0.57	0.49	0.55
Harvested rice area > CH ₄	0.410	0.363	0.409	0.463	0.503	0.482	0.518	0.535	0.475	0.524	0.568	0.488	0.547
4 - WASTE	7.41	7.15	7.42	7.43	7.46	7.01	6.90	6.86	7.07	7.05	6.82	6.91	6.79
4A - Solid Waste Disposal	6.58	6.29	6.54	6.54	6.55	6.10	5.98	5.92	6.12	6.06	5.82	5.89	5.78
4A1 - Managed Waste Disposal Sites	6.58	6.29	6.54	6.54	6.55	6.10	5.98	5.92	6.12	6.06	5.82	5.89	5.78
Landfills > Landfill Emissions - Landfill Gas > CH ₄	6.581	6.291	6.540	6.536	6.541	6.087	5.973	5.910	6.100	6.041	5.804	5.878	5.785

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Air Resources Board

DRAFT Documentation of California's Greenhouse Gas Inventory

Index last updated on August 07, 2007

Data documentation is a critical part of any inventory. This webpage provides links to draft documentation pages for the data and methods used in developing the statewide GHG inventory. Each link allows users to access information on estimated emissions, computations, activity data and other parameters for each year from 1990 to 2004. The categories in this index are based on those defined in 2006 by the Intergovernmental Panel on Climate Change (IPCC).

— Index to the Documentation Pages —

- ⊕ 1 - ENERGY
- ⊕ 2 - INDUSTRIAL PROCESSES AND PRODUCT USE
- ⊖ 3 - AGRICULTURE, FORESTRY, AND OTHER LAND USE
 - ⊖ 3A - Livestock
 - ⊖ 3A1 - Enteric Fermentation
 - ⊕ 3A1a - Cattle
 - ⊖ 3A1c - Sheep
 - [Livestock population - Sheep > CH4](#)
 - ⊕ 3A1d - Goats
 - ⊕ 3A1f - Horses
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 - ⊕ 3A2 - Manure Management
 - ⊕ 3B - Land
 - ⊕ 3C - Aggregate Sources and Non-CO2 Emissions Sources on Land
- ⊕ 4 - WASTE



Air Resources Board



Documentation of California's Greenhouse Gas Inventory

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► Category: Enteric fermentation - Sheep

IPCC: 3A1c - Sheep

Sector: Agriculture & Forestry : Enteric Fermentation : Other Livestock : None

► Greenhouse gas: CH₄

♦ 1990 CH₄ from Livestock population - Sheep

• Greenhouse gas estimation —

Amount: 8,000 metric tonnes of CH₄ emitted (168,000 metric tonnes CO₂eq.)

Basis: Calculation

Calculation: [Livestock population] * [CH₄ emission factor]

Reference: IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston HAS., Biennia L., Miwa K., Negara T. and Tanabe K. (eds). Vol.4, Chap. 10. Published: IGES, Japan.

• Activity level —

Amount: Livestock population = 1,000,000 head of Sheep

Basis: Data

Reference: USDA (2006) U.S. Department of Agriculture, National Agriculture Statistics Service, California Statistics. Available online at: <http://www.nass.usda.gov/Statistics_by_State/California/index.asp>

• Parameters and Constants used in calculations —

Parameter: CH₄ emission factor = 8000 g / individual

Reference: IPCC (2006) 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Eggleston HAS., Biennia L., Miwa K., Negara T. and Tanabe K. (eds). Vol.4, Chap. 10. Published: IGES, Japan.

Constant: Global warming potential of CH₄ = 21

Reference: IPCC (1996). Second Assessment Report. Climate Change 1995: WG I - The Science of Climate Change. Intergovernmental Panel on Climate Change; J.T. Houghton, L.G. Meira Filho, B.A. Callander, N. Harris, A. Kattenberg, and K. Maskell (eds.); Cambridge University Press. Cambridge, U.K.

• Greenhouse gas emitted per unit activity —

Amount: 8.00 kg of CH₄ per head of Sheep



1990 Emissions Level

Role of Inventory

- Statewide 1990 emissions level is basis for statewide, aggregated 2020 limit
- Starting point for Scoping Plan development

Statewide 1990 Emissions Level

- Comprehensive of all anthropogenic emissions
- Excludes international bunker fuels (marine and aviation)
- Aggregated number: 436 MMTCO₂ Eq

Statewide 1990 Emissions Level (*cont.*)

- Consider excluding domestic aviation
 - Equals approximately 24 MMTCO₂ Eq
- Rationale:
 - State has no direct control over aviation-related fuel and emissions control technologies
 - Interstate aviation akin to international aviation at statewide level

2020 Emissions Limit

- Equivalent to 1990 emissions level
- Statewide, aggregate emissions
- Limit not sector- or facility-specific
- Remains in effect unless otherwise amended or repealed

2020 Projections

- Ongoing work
- CAT projections based on 2003 IEPR
- CEC projections based on 2005 IEPR
- Draft 2007 IEPR under review
- Considering similar projection methodology to CEC

Schedule

- Early Fall 2007

- Draft staff report

- December 2007

- Board consideration of GHG inventory and 1990 level / 2020 limit in public hearing



Comments or Questions?



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GHG Inventory Website

<http://www.arb.ca.gov/cc/ccei/ccei.htm>



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